GA-C21971
(3/31/95)

ELECTROACTIVE ELASTOMERIC STRUCTURES (EAES) FOR HYDROACOUSTIC APPLICATIONS R&D STATUS REPORT

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Prepared under
Contract No. N00014-94-C-0264
for the
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GENERAL ATOMICS PROJECT 3711
APRIL 1995

GENERAL ATOMICS

R&D Status Report

Smart Materials and Structures

Electroactive Elastomeric Structure (EAES) for Hydroacoustic Applications

ARPA Order No.: BAA-94-17

Program Code No.: Not Applicable

Contractor: General Atomics

Contract Amount: $739,177.00

Contract No.: N00014-94-C-0264

Effective Date of Contract: 29 September 1994

Expiration Date of Contract: 30 September 1996

Principal Investigator: Dr. Terry D. Gulden

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Short Title of Work: Electroactive Elastomeric Structure (EAES)

Reporting Period: 1 January 1995 through 31 March 1995

DESCRIPTION OF PROGRESS

The emphasis in the second quarter of the program has been on materials formulation and preparation for the initial performance test series. The redesign and construction of a square cross section flow path for the NUWC quiet water tunnel has been a major effort that has now been successfully completed. Improved electroactive elastomers have been formulated using advanced electrorheological materials that have substantially increased the materials response.

MATERIALS FORMULATION AND QUALIFICATION TESTING

Materials Selection. A baseline electroactive elastomer material design was selected for the pending performance test series at NUWC. The selected material consists of a specially formulated ER fluid from ERFD, Ltd., identified as Ressil 35/815 (35 volume % Reslinol 815 particles mixed in Dow Corning #200 Fluid, a polydimethylsiloxane oil of 20 centistoke dynamic viscosity). It is made up of 87 wt% of elastomer with 6.5 wt% silicone resin and 6.5 wt% catalyst. This elastomer was selected based on dynamic shear (G, G' and G") performance. These parameters were determined for two other elastomer designs which also incorporated the Reslinol 815 particles. One elastomer had a smaller concentration of particles for a similar resin content while the other consisted of a greater content of resin. The difference in G' and G" for the three electroactive elastomers was substantial; and the electrorheological effects were substantially more pronounced than observed earlier for the baseline electroactive elastomer, which utilized cornstarch particles.

Static shear measurements (at shear strain < 8%) of the baseline EAES yielded a G value of 2400 Pa for the zero electric field condition, which increased to 8050 Pa with an applied electric field of 3.33 kV/mm.

Materials Characterization. Two methods of optical light microscopy were investigated and compared as tools for microstructural examination. Reflected light microscopy at magnifications of 100X and 200X was most revealing in the delineation of the elastomeric matrix component of the composite. Transmitted light microscopy at the same magnifications was most useful in the resolution of microfeatures such as the size and shape of the active particles and their relationships to the elastomeric matrix. Techniques of specimen preparation (e.g., excising small pieces from larger, fabricated composites) were part of the investigation. Manual slicing of thin (300 micron) specimens was found to permit clear distinction of particles under transmission. The cell structure of the elastomeric matrix was observable by reflected light microscopy but not by transmitted light microscopy.

PERFORMANCE TESTING

Quiet Water Tunnel. A square duct configuration has been adopted for the flow tube configuration for the quiet water tunnel at NUWC. This configuration greatly simplifies the test article fabrication with no loss in test quality. An extended (50 ft long) square duct has been constructed and delivered to NUWC. The square duct internal dimension selected (2.4 in. x 2.4 in.) was the largest that would fit into the 3 1/2 in. inside diameter of the water tunnel transition section. The duct was fabricated from 1 in. thick acrylic, which was glued and bolted into manageable lengths for assembly at NUWC. For experimental flexibility, four different section lengths were selected to accommodate variable flow development conditions and experimental configurations as detailed in Table 1.

Table 1
Duct Section Configuration

Number of Sections	Section Length	Function
4	8 ft	Two each for flow development and outlet sections
2	4 ft	Trim sections for flow development optimization
1	6 ft	Final outlet section
2	1 ft	Dummy test sections (can be instrumented later if required)
1	1 ft	EAES Test Section (EAES specimen with seven pressure transducers)
1	1 ft	Baseline Section (foil velocity and seven bare surface pressure transducers)

Each duct section was fitted with o-ring seats and acrylic flanges. Considerable care was devoted to contouring the inside duct surface to assure smooth flow profiles.

Two in. thick Delrin blocks with a square internal cross-section serve as the transition sections between the water tunnel input and output flanges. These blocks will be firmly bolted to the water tunnel support structure to accommodate the kinetic flow forces developed at the transition from circular to duct flow. Hard rubber sections (1/4, 1/8 and 1/16 in. thick) will be inserted at the outlet transition block to account for length errors resulting from tolerance stackup (o-ring seals at the flanges).

The duct material has been received and machined to shape and all sections have been assembled. The duct was shipped to NUWC with the first EAES test section sample in the first week of April.

Forming and Fabrication Procedures Development. The adoption of a square duct flow channel greatly simplifies the test sample design for the quiet water tunnel. The EAES material can now be molded in place, in a depression, in one of the channel section faces. The EAES material depression will be 2 in. wide x 7 in. long. The depth of the depression will depend on the electrode configuration, which will vary from test to test.

The electrode structure is a metallized scrim cloth imbedded within the EAES material. The placement of electrodes for the water tunnel test samples is dictated by the conditions of the test and the active EAES volume desired. Because the pressure sensors are mounted at the bottom of the sample, under the EAES material, the electrode closest to the sensors must be at ground potential to avoid arcing to the instrumentation. This then forces the outermost electrode, closest to the water, to be at high voltage. Since the water used in the water tunnel is not de-ionized, a relatively thick insulating layer is required between the outer electrode and the water surface when utilizing a two-electrode structure.

To help mitigate this problem and to enhance performance, a three-electrode structure has been designed which places electrodes at ground potential at both top and bottom, with the high voltage electrode centered in the elastomer between them. This configuration provides for a maximum active EAES volume and relieves the problem of arcing to water. Only a thin insulating elastomer layer is required between the outermost electrode, which is at ground potential, and the water surface. The three-electrode design should have approximately double the performance for a given surface area. Both two and three electrode test samples will be tested in the first series of performance tests at NUWC. A third test will be included in the first series to ascertain the effects of the presence of the scrim electrodes on the sensor response. This test will utilize a test sample constructed in a manner identical to a two-grid system but without scrim electrodes in place. Baseline zero voltage runs will be performed to determine whether the presence of the scrim cloth has any effect on sensor response.

Three different approaches to incorporating scrim electrodes into the EAES structure have been evaluated, as shown in Fig. 1. The first was the same approach used in the feasibility test series as reported in the last quarterly report. Foam strips were glued to the sides of the depression to enhance bonding. The scrim electrodes were then attached to the top and bottom surfaces of the foam. Because the foam was not rigid, the electrodes could not be maintained parallel to each other over the entire EAES surface area. The top electrode always displayed a degree of sag, which brought it into close proximity to the ground potential electrode in at least one location causing a local electrical breakdown. This condition severely limited the high voltage that could be applied to the active EAES volume.

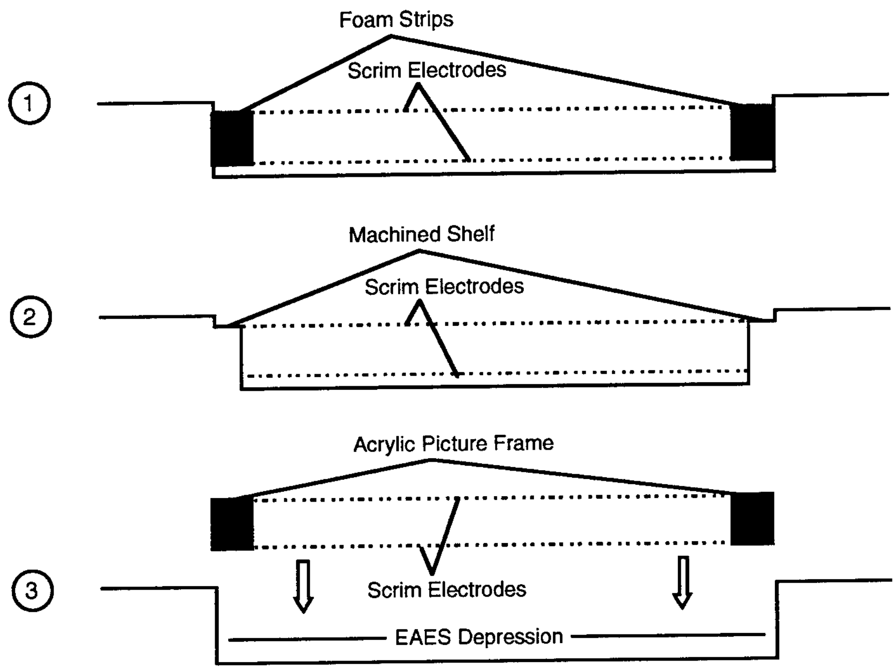

Fig. 1. Electrode attachment concepts

The second technique attempted was to cut a shelf around the outer perimeter of the EAES depression to serve as a bonding surface for the upper scrim electrode. While it was possible to maintain a higher degree of parallelism in this configuration, some sag never-the-less resulted, again limiting the maximum allowed voltage. Approximately one third of the control range was effected.

The final approach to the electrical design took the form of a picture frame structure wherein the scrim electrodes were fastened to the frame in a separate operation and then inserted into the EAES depression along with their respective voltage feed-throughs which exit the structure at the bottom of the acrylic plate. This technique allowed a slight tension to be applied to the scrim electrodes as they were positioned over the frame in preparation for fastening. This resulted in the desired uniform spacing between electrodes and eliminated the problem with premature electrical breakdown. The first two test samples, both two and three grid structures, being sent to NUWC are being assembled using this technique.

The required thickness of the surface insulating elastomeric layer in the two electrode design was determined by a series of experiments to be four fifths of the thickness of the electroactive material for a maximum electric field of 4 kV/mm. For the three electrode design, because the top electrode is at ground potential, the surface layer only needs to be sufficiently thick to provide physical protection.

The anechoic test article design has been completed and the first test article has been fabricated. NUWC requested a baseline test article be fabricated without the electrode structures in place. This test article has been fabricated and will be shipped with the duct assembly. The first calibration runs are scheduled for the first week in May with test article runs scheduled for the following week.

SCHEDULE STATUS

The program schedule is shown in Fig. 2. Two major factors have combined to result in approximately a one month delay in the completion of the first performance test series. A major factor in the slippage was the change in the sample configuration for the quiet water tunnel tests that necessitated the design and fabrication of a completely new, square cross section, flow path. The hardware is now completed and has been shipped to New London. The same flow path will be used for future tests so the additional work up front should make the job easier in the later tests.

At the same time NUWC has had permitting problems with the effluent water from the quiet water tunnel. Even though only city water with nothing added is being dumped into the city water system, problems have been encountered with obtaining a permit. It is now believed that the permit can be obtained in time to begin testing in May.

SUMMARY OF SUBSTANTIVE INFORMATION DERIVED FROM SPECIAL EVENTS

An informal program review was presented on March 1 to Dr. Bob Crow, manager of the ARPA Smart Materials and Structures Program.

PROBLEMS ENCOUNTERED AND/OR ANTICIPATED

The completion of the first performance test series has been delayed approximately one month. It is anticipated that this delay can be made up in the future so that no significant impact on the overall program is currently anticipated.

ACTION REQUIRED BY THE GOVERNMENT

No action required.

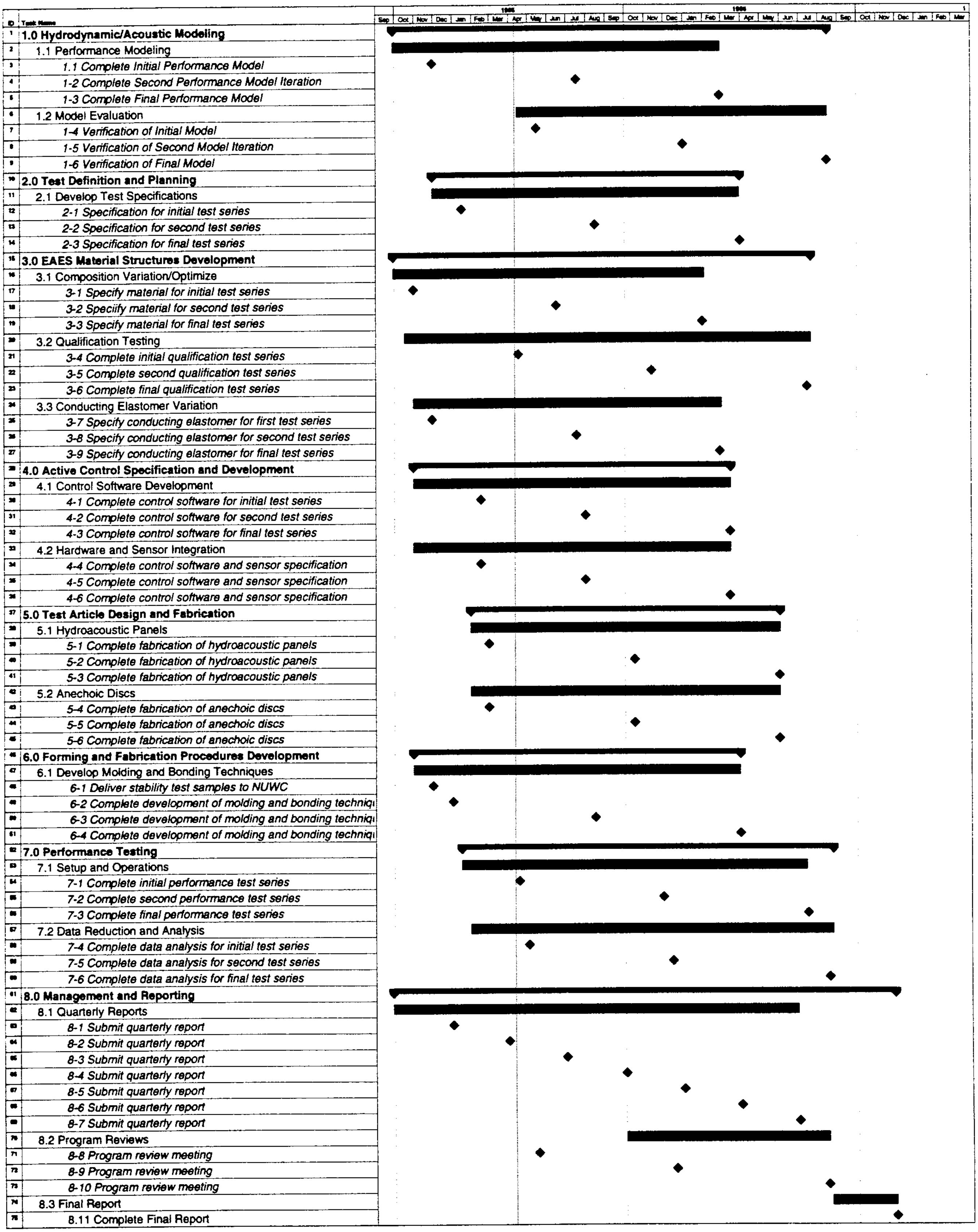

Fig. 2. Program schedule

FISCAL STATUS

1. Amount currently provided on contract: $600,000 (incremental funding)
2. Expenditures and commitments to date: $227,287 (as of 31 March 1995)
3. Funds required to complete work: $511,890